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**REMOTELY CONTROLLED REAGENT FEED SYSTEM FOR
MIXED WASTE TREATMENT TANK FARM**

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REMOTELY CONTROLLED REAGENT FEED SYSTEM FOR MIXED WASTE TREATMENT TANK FARM

ABSTRACT

Lawrence Livermore National Laboratory (LLNL) has developed and installed a large-scale, remotely controlled, reagent feed system for use at its existing aqueous low-level radioactive and mixed waste treatment facility (Tank Farm). LLNL's Tank Farm is used to treat aqueous low-level and mixed wastes prior to vacuum filtration and to remove the hazardous and radioactive components before it is discharged to the City of Livermore Water Reclamation Plant (LWRP) via the sanitary sewer in accordance with established limits.

This reagent feed system was installed to improve operational safety and process efficiency by eliminating the need for manual handling of various reagents used in the aqueous waste treatment processes. This was done by installing a delivery system that is controlled either remotely or locally via a programmable logic controller (PLC). The system consists of a pumping station, four sets of piping to each of six 6,800-L (1,800-gal) treatment tanks, air-actuated discharge valves at each tank, a pH/temperature probe at each tank, and the PLC-based control and monitoring system. During operation, the reagents are slowly added to the tanks in a preprogrammed and controlled manner while the pH, temperature, and liquid level are continuously monitored by the PLC. This paper will present the purpose of this reagent feed system, provide background related to LLNL's low-level/mixed waste treatment processes, describe the major system components, outline system operation, and discuss current status and plans.

INTRODUCTION

The LLNL Tank Farm is used to treat aqueous hazardous and mixed wastes prior to discharge to the LWRP via the sanitary sewer in accordance with established discharge limits. The facility consists of six open-top conical bottom tanks, each with a 6,800-L (1,800-gal) capacity. The aqueous wastes are batched together following specific procedures and then pumped to one of the treatment tanks. In the tank, the wastes are treated by adding various reagents to perform neutralization, oxidation, pH control, chelation/flocculation, adsorption, and other chemical processes. These processes are performed to facilitate subsequent filtration of the waste water in the LLNL Waste Water Vacuum Filtration Unit. More detail regarding aqueous waste treatment processes performed at the LLNL Tank Farm is provided in the referenced document. The Tank Farm is regulated under Title 40 of the Code of Federal Regulations (CFR) Section 264, Subpart J, "Tank Systems," and Title 22, Section 66264.190 of the California Code of Regulations (CCR).

Before this semiautomated feed system was completed, reagents used during the Tank Farm treatment processes were added to the tanks manually. An operator pumped a reagent from a storage drum into a wide-mouth, 19-L (5-gal) carboy; physically carried the partially filled carboy to the edge of the selected treatment tank; and poured the contents into the tank. When adding reagents such as ferric sulfate or hydrogen peroxide, only one trip between the pump and the tank was needed because of the small amount of reagent required. However, when large amounts of acids or bases are required, several trips to and from the tank were needed to add these reagents. As a result, this method, although performed under the strictest of safety procedures, had the potential for compromising safety and efficiency of the facility.

For example:

- A carboy of reagent, weighing up to 15.9 kg (35 lb), could be dropped or spilled onto an operator.
- A carboy (although labeled well) could be accidentally used for a different reagent which, if residue was present, might react with the reagent being added.
- The quantity of reagent added could be inaccurate because of the lack of control during the addition (volumes were estimated by the operator and overshooting of the pH endpoint was common).

The new remotely controlled reagent feed system eliminates the need for contact handling of the reagents and thereby improves operational safety and process efficiency. This was done by designing, installing, and activating a hard-plumbed reagent handling system that is controlled remotely by an operator via a PLC. The overall treatment processes are the same as with the manual system, i.e., the quantities of reagents added to the tanks to treat each waste batch, and the chemical treatment methods did not change.

SYSTEM DESCRIPTION

The remote reagent handling system uses hard-plumbed lines to add the reagents directly into the treatment tanks. There are various control stations where an operator can remotely control reagent addition to any of the six tanks. Completely independent lines are provided for each of the four primary reagents.

The overall system, illustrated in Figure 1, consists of a pumping station, four sets of piping to each of the six Tank Farm tanks, actuated discharge valves at each tank, a pH/temperature probe at each tank, and a PLC system. Each reagent has one pump circuit associated with it (one circuit for each drum of reagent).

Pumping Station

The pumping station was installed on a platform located at the southeast corner of the LLNL Tank Farm facility (see Figure 2). An enclosure was installed around the pumping station to protect it from the elements and for aesthetics. The enclosure has a roll-up door on the front to allow forklift access for changing reagent drums and for pump station maintenance. The pumping station consists of four diaphragm metering pumps and various other components that are configured into four complete pumping circuits. All four pump station circuits are mounted on a platform that is approximately 4.3 m long × 0.8 m wide × 1.2 m high (14 ft × 2-1/2 ft × 4 ft). The reagent drums are stored directly in front of the platform and are connected to the suction sides of the pumping circuits using drum stingers made of Teflon-lined, stainless steel, webbed flexible hoses with quick disconnect fittings.

Each of the four pumping circuits use an electrically driven diaphragm metering pump. The pumps have a maximum dynamic pumping capacity of 170 L/h (45 gal/h) that can be metered down to less than 17 L/h (4.5 gal/h) minimum flow by manually adjusting the stroke length of the pump with a micrometer device. Each of the pump circuits has a backpressure valve located in its discharge line to assure proper operation of the metering pump ball valves.

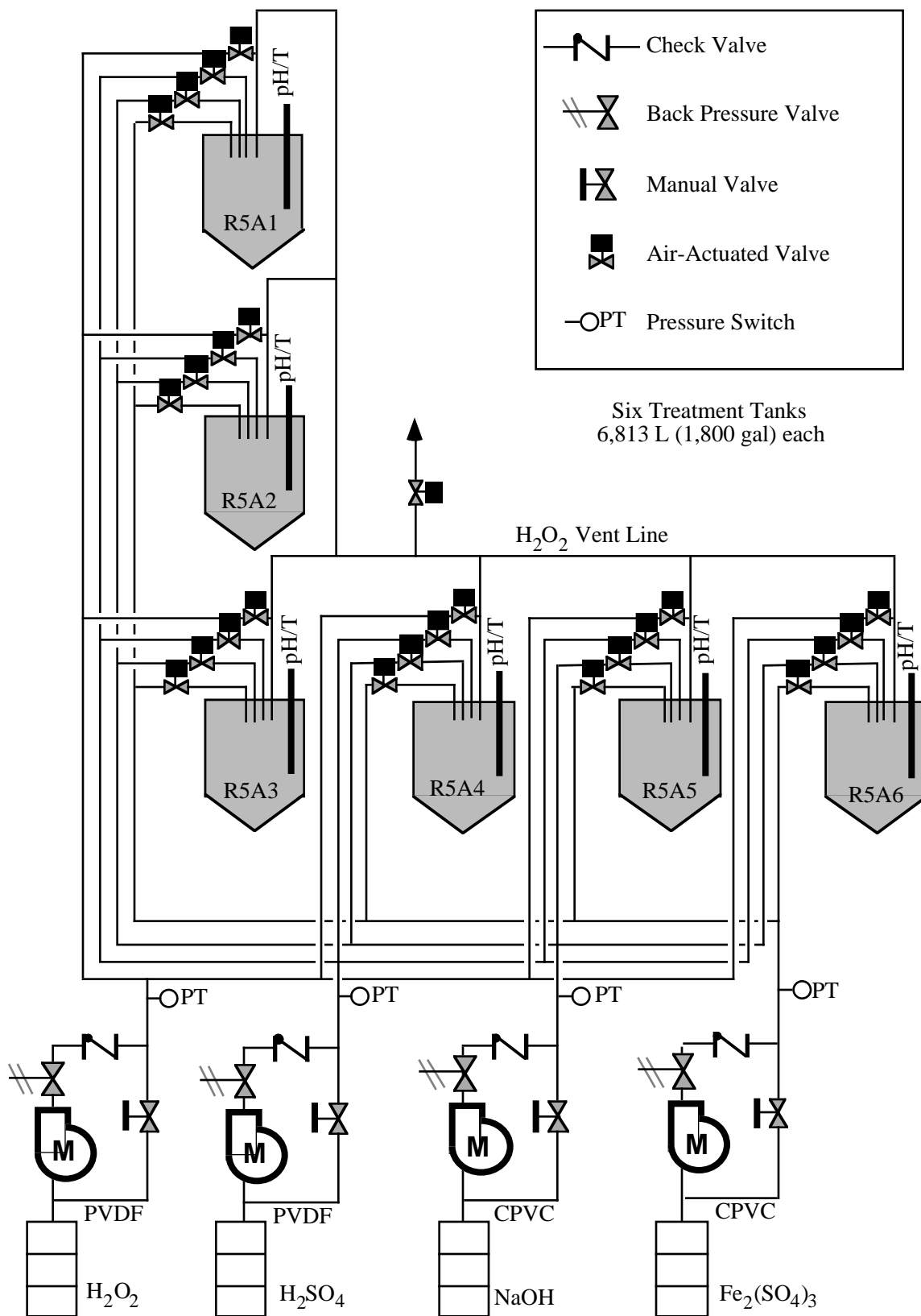


Figure 1. Remote Reagent Handling System Piping Schematic.

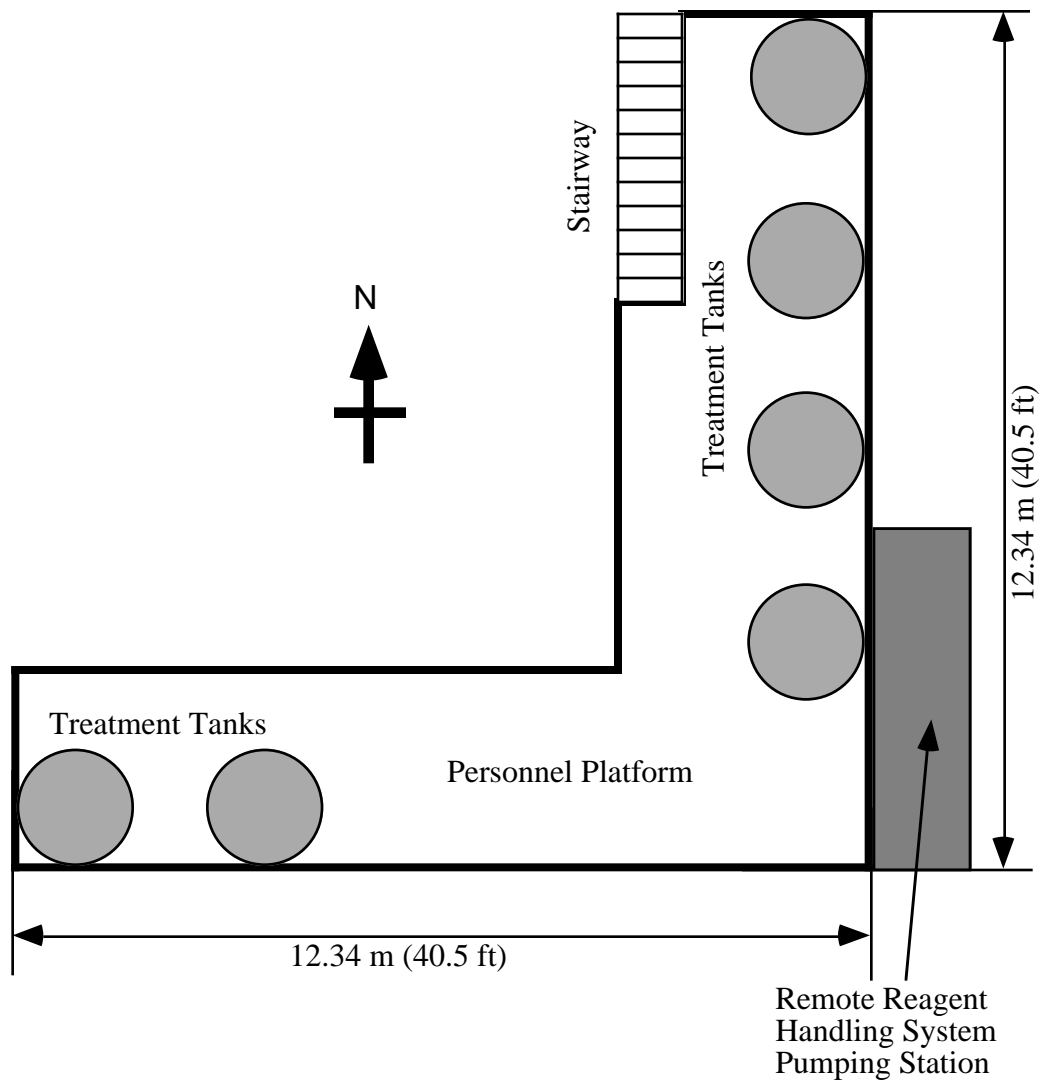
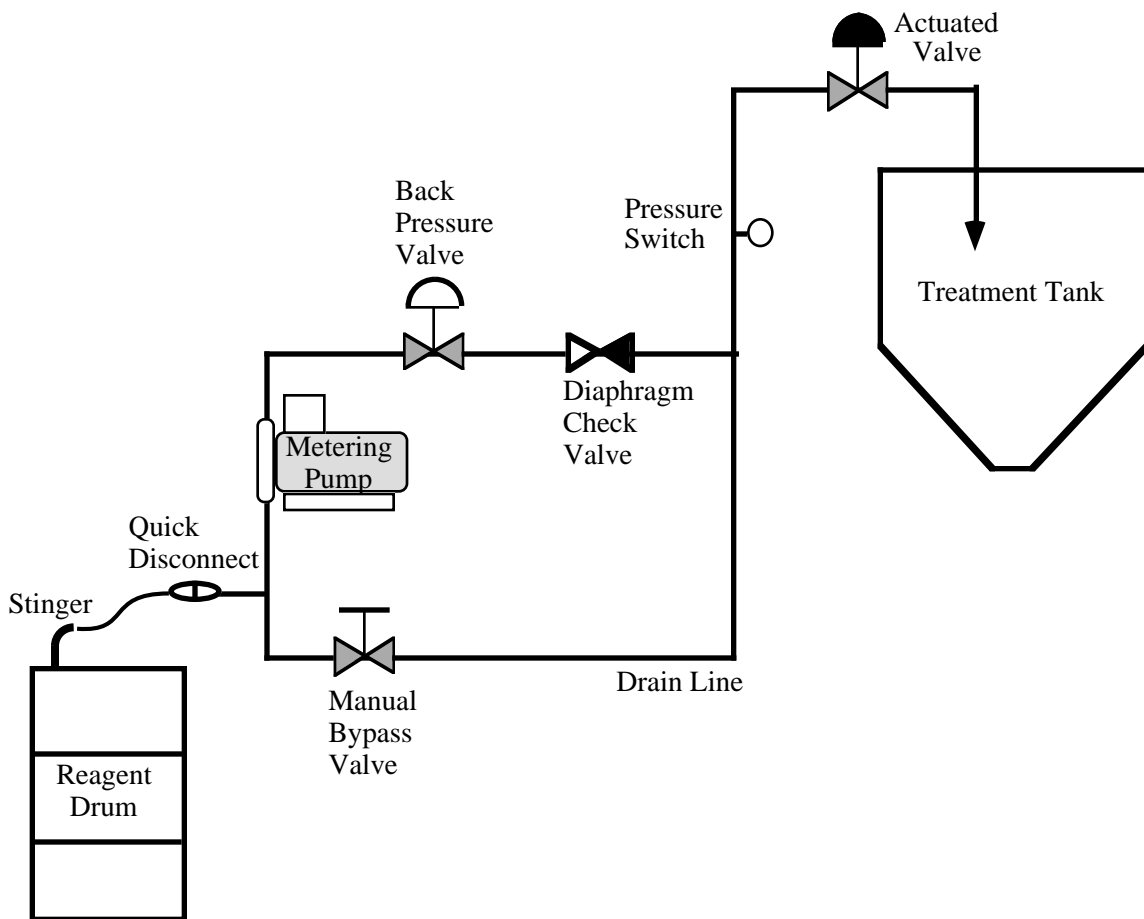


Figure 2. LLNL Waste Treatment Tank Farm Facility.

In addition, a check valve is located after each backpressure valve to prevent backflow through the pump when it is not operating and to maintain reagent in the discharge lines at all times. A bypass/drain line is located in each pumping circuit to facilitate draining of the entire circuit during maintenance activities. A typical metering pump circuit configuration is shown in Figure 3.

The first pumping circuit is used to adjust the pH in the waste treatment tank by inserting acid solutions. These acid reagents are used primarily to neutralize the wastes and to facilitate the oxidation of metals with the hydrogen peroxide reagent, which is added later in the treatment sequence. The wetted components of this pumping circuit are made of polyvinylidene fluoride (PVDF) plastic, viton, and Teflon, which are all compatible with sulfuric acid (H_2SO_4), the most common reagent used with this circuit.



**Figure 3. Typical Metering Pump Circuit Piping and Flow Diagram.
(One tank only is shown for clarity)**

The second circuit is used to feed hydrogen peroxide into the waste blend to oxidize hazardous constituents. This system is also used (after clean-out) to transfer bleach solutions, such as concentrated hypochlorite solution, to the waste blend to oxidize cyanides and cyanates. The wetted components of this pumping circuit are also made of PVDF plastic, viton, and Teflon, which are all compatible with hydrogen peroxide (H_2O_2) and the other reagents planned for this pump.

The third circuit is used to feed sodium hydroxide solution into the blend to adjust the pH. This is used primarily for neutralization and hydroxide precipitation of the wastes. This hydroxide pump is also used, when necessary, to feed other reagents—such as chelators, carbonates, sulfides, reducing agents, carbon slurries, and hypochlorite solutions—into the blend. However, before any reagents other than sodium hydroxide are fed, the pump has to be cleaned out. The wetted components of this pumping circuit are made from chlorinated polyvinyl chloride (CPVC) plastic, EPDM rubber, and Teflon, which are all compatible with sodium hydroxide (NaOH) and the other anticipated reagents.

The fourth circuit is used to feed various flocculates into the waste blend to encourage the formation of solids, which improves efficiency of removing the hazardous components in the Waste Water Filtration Facility. All changes to different flocculates used require pump cleanout. The wetted components of this pumping circuit are made of CPVC plastic, EDPM rubber, and Teflon, which are all compatible with ferric sulfate $[\text{Fe}(\text{SO}_4)_3]$ which is the most common reagent used with this pump.

Lines and Piping

Each of the reagent suction lines have rigid pipe stingers made of 0.013-m (1/2-in.) nominal diameter plastic tubes, approximately 1.2 m (4 ft) long, which are compatible with the fluid to be pumped. These stingers are inserted into the reagent drums through one of the bung holes and attached using a special bung fitting. The top of each stinger is connected to a Teflon-lined, stainless steel webbed flexible hose with a nominal internal diameter of 0.013 m (1/2 in.) and a length of about 0.30 m (1 ft). Each of these hoses is equipped with a Teflon-sealed, stainless steel quick-disconnect male fitting that is compatible with the reagent fluid being pumped. During operation, each stinger hose is attached to its corresponding pump suction line via a female quick-disconnect permanently mounted on the pump station. All quick disconnects are color coded as to reagent type and designed so that the male and female fittings will not connect if an attempt is made to attach a particular reagent stinger to the wrong pumping circuit.

The discharge piping to the treatment tanks is hard plumbed, using 0.013-m- (1/2-in.-) diam plastic lines made of materials that are compatible with the various pumped reagents. Each pumping circuit consists of one, 0.013-m- (1/2-in.-) diam riser that extends from the pumping station platform up to a horizontal header pipe that runs the length of both orthogonal sections of the treatment tank personnel platform. At locations just below each of the six treatment tanks, 0.013-m (1/2-in.) lines rise from the horizontal header to the top of each of the tanks, where they connect to the actuated discharge valve for that particular reagent. All four pumping circuits are independent of each other, and all can pump reagents to any one of the six treatment tanks. Therefore, there are four independent discharge lines rising to each tank, one from each pumping circuit.

The four piping runs are mounted together inside a thin-wall, stainless steel channel with a Lexan splash shield on the front, which is there mainly for aesthetics. The shield can protect the operators from contact with any direct spray due to pipe failures. However, it is not meant to completely contain the reagents in the event of a pipe leak. The secondary containment berm for the Tank Farm can contain any leaks or spills from these pipe lines.

Because of its susceptibility to drastic viscosity changes at low temperatures, the sodium hydroxide pumping circuit piping is wrapped with insulation and contains a heating element along its entire length. Drum heaters are also attached to the sodium hydroxide reagent drum. The heaters are automatically controlled to maintain a constant sodium hydroxide temperature of about 21–27°C (70–80°F).

One additional system has been added to the hydrogen peroxide pumping circuit to allow for the slow natural disassociation of hydrogen peroxide to water and oxygen. A vent line with a normally open valve was installed to relieve the oxygen pressure buildup from the circuit when it is not being operated. Without a vent line, the pressure in the closed hydrogen peroxide lines builds up rapidly and, if unchecked, could rupture the line. During operation of the hydrogen peroxide circuit, the vent valve is automatically closed to prevent the escape of liquid out of the vent line. The PLC automatically controls this sequence of events, and the operator does not have to perform any special actions.

Actuated Discharge Valves

A total of 24 air-operated valves (six on each pumping circuit) are used to control the discharge of the reagents into the treatment tanks. Each valve consists of a 0.013-m (1/2-in.) ball valve with wetted components that are compatible with the reagents pumped (e.g., CPVC and EPDM rubber for the sodium hydroxide and ferric sulfate reagent lines, and PVDF and viton for the sulfuric acid and hydrogen peroxide reagent lines). All the valves use a 24-Vdc solenoid-driven, air-operated actuator to control valve position. The actuator uses air at 689.5 kPa (100 lb/in.²) to open the valve and a spring return to close the valve. In the event power is lost to the solenoid, the spring will drive the valve to a fail-safe closed position. All the valves have open/closed position indication switches that can be monitored from the PLC. The PLC controls these valves and incorporates interlocks to allow operation of only one valve at a time in order to prevent accidental mixing of reagents in the treatment tanks.

These valves are located on a stainless steel plate mounted to the top of each of the treatment tanks as shown in Figure 4. The discharge lines from these valves terminate above the liquid surface of the treatment tank in order to prevent pipe material compatibility problems with the waste and possible siphoning actions. The discharge nozzles are angled down towards the center of the treatment tank to keep the reagents from contacting the tank walls above the liquid level. During maintenance activities, which may require personnel to work inside the tank, the union and down spout on the discharge side of each of these valves are removed and a screw cap put over the end of the valve discharge to physically prevent any accidental release of reagent to the tank.

Control and Monitoring System

The pumping station is controlled and the measured parameters in each treatment tank are monitored using an Allen-Bradley PLC system. The system is designed to allow the operator, while at a single location, to control and monitor the rate of flow of the liquids through all the reagent pumps and to monitor the pH, temperature, and level status in the treatment tanks.

The operator control stations consist of a backlit alarm annunciator panel and a color CRT-based control terminal. From this terminal, the operator chooses from a variety of available control screens depending on the desired control or monitoring functions. Status of all the Tank Farm and remote reagent system valves, pumps, and tanks are displayed on these control panels. From these control terminals, the operator can configure and execute an entire control sequence, configuring parameters such as desired pH, liquid quantities, and dwell times. The operator can also dispense desired quantities of reagent in a manual mode and control the NaOH heaters from these control terminals.

The metering pumps are turned on and off through the PLC. Flow rate calibration for each of the metering pumps was determined during initial testing and is periodically verified. During operation of the metering pumps in any of the circuits, the pump flow rates and total flows are determined by the PLC as a function of pump motor operation time. This method gives values for flow rates and total flows that are within 5% of the true value.

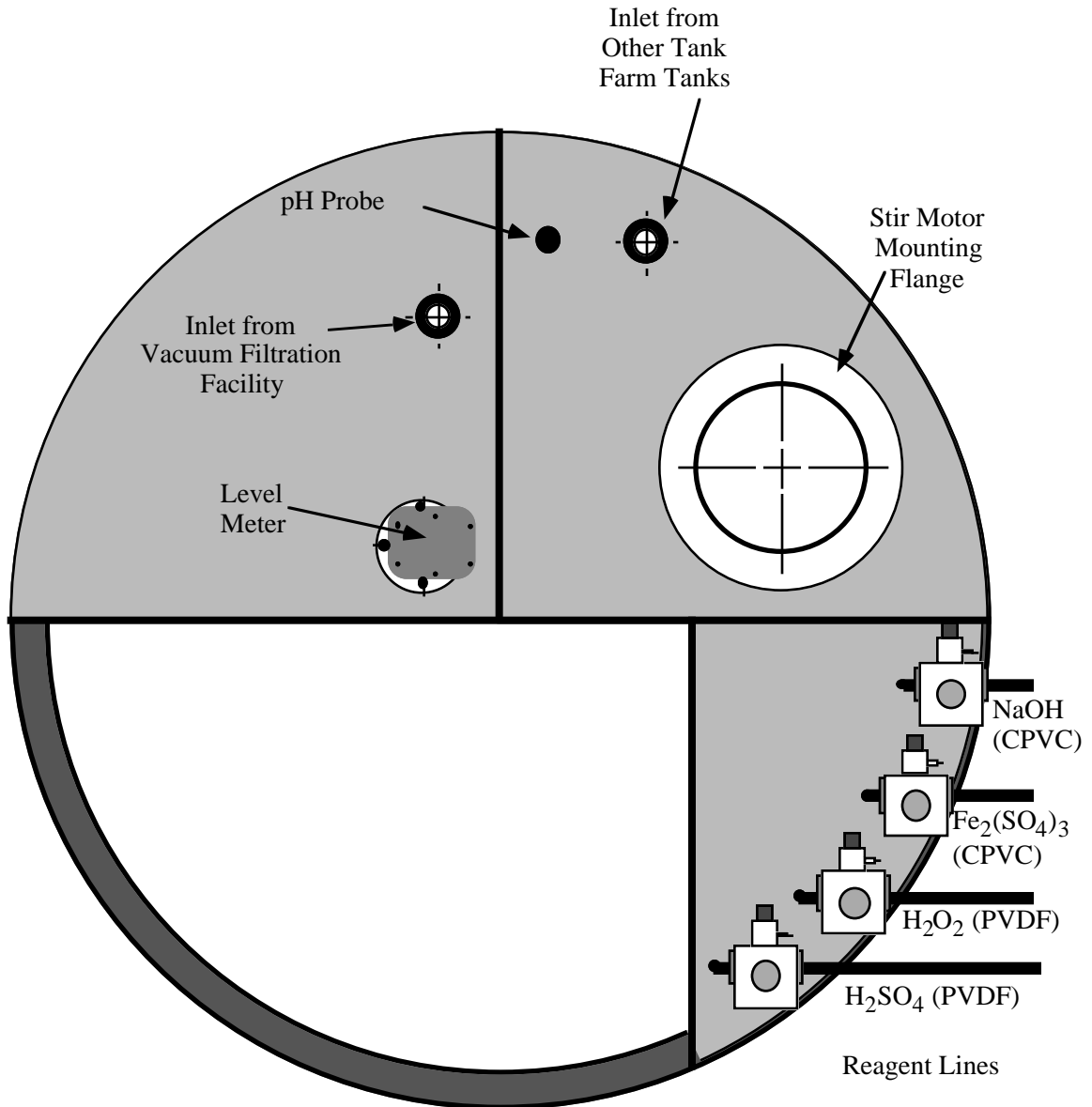


Figure 4. Typical Arrangement of Discharge Valves on Treatment Tank.

As described above, pneumatically operated air-open/spring-return actuators are used to open and close all the reagent discharge valves on the system (see Figure 1). The air to these actuators is switched on and off using 24-Vdc solenoids controlled from the PLC. In addition, the position indicator signals from each of the valves are used to verify valve open-closed status at the PLC.

A permanently mounted, combined pH and temperature sensing probe is submersed into the fluid of each treatment tank during the entire batch process. The sensors are attached to the lower end of a 0.019-m- (3/4-in.-) diam stainless steel tube that is 1.52 m (5 ft) long. The tubes are mounted to the treatment tank lids using a compression-type fitting that allows the tube to be completely withdrawn from the tank for calibration, storage, and maintenance of the pH probe. See Figure 5 for the arrangement of the pH probe.

The transmitters for the pH probes are housed adjacent to the tanks. From this location, the operators can perform calibration procedures and execute various maintenance functions on the pH system.

During operation the PLC continuously monitors the pH and temperature readings from each of the treatment tanks. If, during the insertion of reagent into the treatment tanks, the pH reading rises above or drops below operator-selected set points then, the controller will automatically shut off the pump that is adding the reagent and alert the operator.

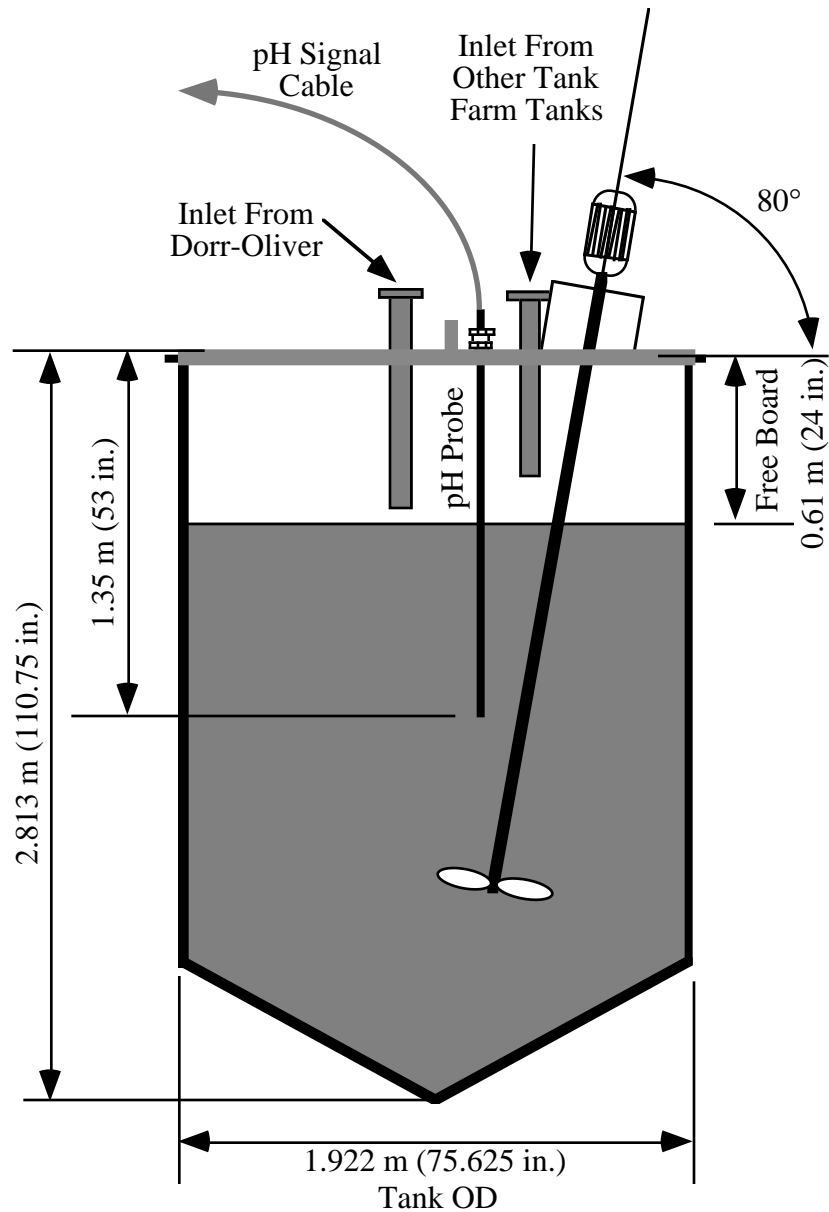


Figure 5. Tank Farm pH Probe Mounting Arrangement.

Ultrasonic level indicators are also mounted on each of the tank lids. If the tank is filled to the high-level point, an alarm will be enunciated by the PLC to alert the operator. If the tank filling continues to the high-high level, then the PLC will automatically shut off the pump and all other fill paths to the tank to prevent overflow and alert the operator with an annunciation alarm.

Pressure switches are installed in each reagent line to prevent inadvertent over-pressurization of the system. If one of these switches is activated, the corresponding pump is immediately shut down, and the condition is annunciated to the operator. As an additional safety feature to prevent over-pressurization, the hydraulic bypasses in the metering pumps are set to approximately 344.7 kPa (50 lb/in.²).

The entire system is interlocked to prevent unintended operational modes. For example, only one reagent pump is allowed to operate at a time, and only one discharge valve is allowed to open. All other reagent pumps remain off, and all other valves remain shut to prevent inadvertent mixing and possible chemical reactions between the various reagents. In addition, easily accessible Crash buttons are placed at various locations around the Tank Farm and near the control locations to allow for emergency shutdown. This PLC-based system also controls and interlocks all of the other Tank Farm operations.

OPERATIONAL OVERVIEW

Description of Reagents

The normal reagents used with the Area 514 Waste Water Tank Farm are sulfuric acid (66 Be), sodium hydroxide (50% by weight), ferric sulfate (50% by weight), and hydrogen peroxide (30–50% by weight). All these reagents have corrosive properties. Sulfuric acid is especially dangerous as a material dehydrator; it strips water from minerals and generates extreme heat. Hydrogen peroxide is a strong oxidizer that can produce oxygen quite readily, providing a significant combustion hazard.

The addition of either sulfuric acid (H₂SO₄) or sodium hydroxide (NaOH) is used to adjust the pH of the waste in order to facilitate oxidation. The use of either the acid or the base depends on the initial pH value of the waste. Hydrogen peroxide (H₂O₂) is added to raise the oxidation state of metals and break up the organics. Ferric sulfate (Fe₂(SO₄)₃) is used for coagulation and precipitation of particles out of the solution. From time-to-time, other reagents may be used to perform the following treatments: precipitation with sulfide and/or carbonate and/or hydroxide, chelation, coagulation with a polyelectrolyte, reduction of hexavalent chromium, and oxidation of cyanide. Most of the reagents used to perform these other treatments will be inserted manually or through the sodium hydroxide pump after being thoroughly cleaned out.

Performance Characteristics

The metering pump circuits can supply precise reagent flow of about 170 L/h (45 gal/h) to the treatment tanks. Most treatments require 0–1.9 L (0–0.5 gal) of ferric sulfate or hydrogen peroxide, and about 11–38 L (3–10 gal) of sulfuric acid or sodium hydroxide per batch. During operation, the reagents are slowly added to the tank in a controlled manner while the pH, temperature, and liquid level are continuously monitored.

During checkout operations on the pump station, it has been shown that the net positive suction head characteristics of the metering pumps are critical to proper operation of the system. Any abnormality in the suction line of the pump that causes increased resistance to flow (e.g., viscosity increase of NaOH due to cold weather, kink in the stinger line, increased lift from reagent drum, air leak in suction line, etc.) can affect the pumping rate of the metering pump. In order to maintain proper operation and assure accurate flow readings from the PLC, a strict procedure is being established to be followed whenever maintenance is required on the suction line components. This includes care in changing out the reagent drums and reinstalling the drum stinger tubes.

STATUS AND PLANS

The hardware for the remote reagent system was installed in September 1994. Checkout and acceptance testing on the system is being performed and is scheduled for completion by March 1995. Training of operating crews is also underway and detailed procedures are being written. As-built drawings are being completed and certified by independent engineers in order to meet the California Department of Toxic Substances Control regulatory requirements. This system has been incorporated in the existing LLNL Part B Permit as a permit modification.

The PLC system has been expanded to control all Waste Water Treatment Tank Farm and Vacuum Filtration treatment operations. Plans are to incorporate the PLC into the operations of other LLNL waste treatment facilities. These other facilities include a cold vapor evaporator, a centrifuge, a blending station, and a carbon adsorption unit. The goal is to provide safe and efficient operational capability for all LLNL aqueous hazardous and mixed waste treatment facilities.

REFERENCE

Bowers, J. S. and Kidd, S. D. "Treatment of Mixed Waste Coolants," paper for presentation at the *Third Biennial Mixed Waste Symposium* in Baltimore, MD (August 7–11, 1995), Lawrence Livermore National Laboratory, Livermore, CA (February 1995).

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